Appendix C

HYDROLOGIC SIMULATION PROGRAM - FORTRAN MODEL FOR ST. LUCIE BASIN

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DESCRIPTION OF THE ST. LUCIE BASIN

The St. Lucie River Basin (**Figure C-1**) is located on the southeastern coast of Florida, encompassing 780 square miles. The North and South Forks of the St. Lucie River flow into the St. Lucie River Estuary and through the southern portion of the Indian River Lagoon before discharging to the Atlantic Ocean. The Estuary and southern Lagoon together form a 30 square miles tidal influenced water body in which supports a fragile macrophyte-based estuarine ecosystem.

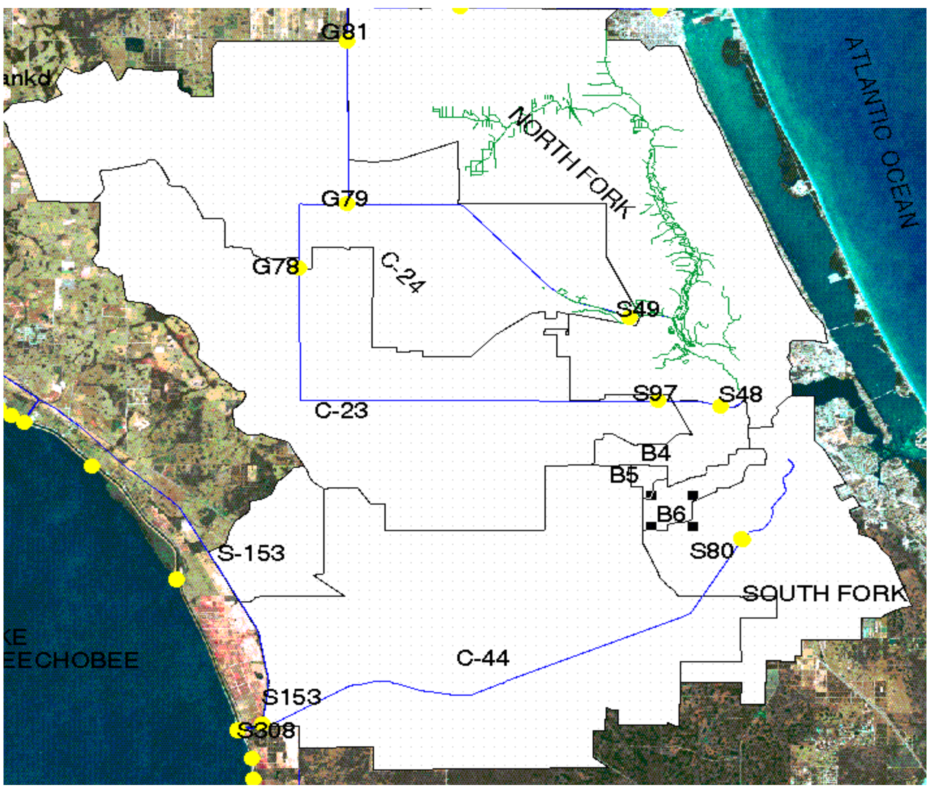

Figure C-1. Primary Drainage Basin in the St. Lucie Estuary Watershed.

The watershed can be divided into the following drainage basins based on major drainage features:

North Fork St. Lucie

C-24 Canal Basin

C23 Canal Basin

C-44 Canal Basin

Basins 4, 5, 6 of the Bessey and Dan Fork Creeks

S-153 Basin

Tidal St. Lucie Basin

The topography of the watershed is described as rising gently from sea level on the east to approximately 30 feet NGVD at the coastal ridge, and then has a very low fat land such as Allapattah flats (elevation at 24 to 30 feet NGVD). The slope of the land becomes steeper to more than 50 feet NGVD to the west. There are areas of depression (wetlands, swamps etc.) and small ridges occur throughout the basin. While soils in the area range from low to high potential seepage rates, the geology of the watershed is dominated by the flatwood soil and soil of sloughs and freshwater marshes, both of which are poorly drained and generally flat.

The climate of the St. Lucie watershed is affected by the sub-tropical influences of the Atlantic Ocean and Lake Okeechobee. Annual mean temperatures is about 73 degree F and Annual rainfall average is about 52 inches per year, and is defined by a wet season from mid May through mid October, during which about 62% of the rainfall occurs. Tropical storms and hurricane season typically occur during wet season, and contribute substantial amount of rainfall.

There are various land use/land covers existed in the area. Agricultural land use is the dominant land cover in the watershed, with citrus groves and improved and unimproved pasture being most extensive. There are scattered tracts of ranged land and scrub/brushlands, and forested uplands occur throughout the area. Forested and non-forested wetlands make up a significant part of the watershed; however, much of the historical wetland areas have been converted to agricultural use. Developed residential and commercial centers are concentrated in the eastern part of the area, near the St. Lucie River.

Since the early 1900s canals and water control structures were built to make the region more suitable for agricultural, industrial, and urban development. The original river basin was about 260 square miles but nearly tripled in size after the construction of numerous irrigation and drainage canals. Flood control releases from Lake Okeechobee can also be made through the canals and are often harmful to the Estuary. These changes to the landscape and drainage have increased peak discharge rates and volumes during storm events, increased sediment and nutrient loads, and all but eliminated base flows to the Estuary during dry periods. The South Florida Water Management District (SFWMD) and U. S. Army Corps of Engineers have jointly undertaken a feasibility study which will develop a regional watershed management plan that will improve the quality and temporal distribution of flows to the Estuary and Lagoon. Hydrologic and hydraulic models of the basin and its canal systems have been developed as part of the study.

The Hydrologic Simulation Program-FORTRAN (HSPF) model was selected for simulating hydrology and the Full Equations Model (FEQ) was chosen for hydraulic routing for the extensive and largely managed canal system under tidal influence conditions and flood conditions where backwater and reversed flow would be a concern. The existing version of HSPF (version 11) was inadequate for simulating wetlands and high water table conditions found within the St. Lucie River Basin. The District contracted the firm of Aqua Terra Consultants to implement changes in the hydrology module of HSPF to allow an improved representation of wetlands conditions and dynamic water table variations common to the South Florida region. This modified version of HSPF will become HSPF12.0 (Version 12). The following paragraphs described the standard version of the HSPF, FEQ, and HSPF12.0:

HYDROLOGIC SIMULATION PROGRAM - FORTRAN

The Hydrologic Simulation Program – FORTRAN (HSPF) simulates hydrologic processes including snow accumulation and melt for overland flow under various land use/land covers, and water quality processes. Channel processes and reservoirs are also simulated. HSPF is a continuous simulation model, and has been used since 1971 in all sections of U.S. and abroad for all types of land use. The time scale of simulation varies from 5 minutes to hourly, depending on the process. Statistical analysis of continuous output time series is used to produce data for economic analysis of alternate water management plans.

The hydrology and hydraulic input requirements of HSPF are precipitation, evaporation, temperature, soil properties, channel properties, land use, topography, supplemental irrigation for crops etc. The output from the HSPF are time series of flow (surface runoff, interflow, base flow, deep seepage into deep groundwater system), stages (ground water tables, water level in stream and river) etc. All input and output time series are stored in HECDSS files for FEQ model or other result presentations.

The components of watershed water quality models of the HSPF are nonpoint source loading simulation and instream simulation. Nonpoint source loading simulation includes runoff quantity (surface and sub-surface), sediment erosion/solids loading, runoff quality, atmospheric deposition, and input needed by instream simulation. Instream simulation includes hydraulics, sediment transport, sediment-contaminant interactions, water quality constituents and processes, point source accommodation, reservoir simulation, and benthal processes and impacts.

FULL EQUATIONS

Full Equations (FEQ) is a one dimensional full equation hydrodynamic flow routing model. The model computes flow and elevation in channel networks for evaluations of the effect of adding, changing, or abandoning a reservoir, effect of operation policy for gates or pumps etc. This model has been applied to various projects by the State of Illinois, (IDOT), county such as DuPage, Snohomish, and King etc. USGS of Illinois, and other consultants. In St. Lucie River basin, FEQ can be used to simulate hydraulic in primary canal and transfers between primary and secondary/tertiary canals. Secondary/tertiary canals represented as Level Pool Reservoirs (LPR).

Primary canal connected to LPR's by culverts and pumps. Input runoff from HSPF (PERLND Module) and irrigation withdraw. Output flow and stage in primary canal and store time series input and output in HECDSS files.

OVERVIEW OF HSPF ENHANCEMENTS

The following assumptions were used in the standard version of the PWATER section of HSPF (version 11 or earlier):

No exact storage locations for surface detention, interflow, upper/lower zone and groundwater storage.

Deep or inactive groundwater is not represented.

The active groundwater storage is not interacted with the unsaturated zone.

Both lower and upper zone storage are not affected by the active groundwater.

No percolation flows from the lower zone to active groundwater.

No limited capacity associated with the interflow storage.

Surface runoff is driven by the ground surface slope, and no evaporation from the surface detention storage.

Many of these assumptions are not valid in South Florida. In the South Florida environment the groundwater is very close to the ground surface. The saturated zone interacts with, and even take over, the unsaturated zone. In many areas the groundwater reaches the surface and submerged the land for days or months. The land is very flat that the surface runoff is not driven by differences in ground elevation. Surface water impoundment is subject to evaporation.

All these invalid assumptions have been enhanced to meet South Florida hydrologic conditions, except the RCHRES (channel/reservoir routing) which is not valid under tidal and backwater conditions. The unsteady flow hydraulic model such as UNET and FEQ can be used in conjunction with the HSPF to rout runoff through channel network system which subject to tidal, backwater, and reserved flow conditions under extremely wet conditions. Due to considerations of data requirements (such as detail channel cross-sections, field operation data etc.), computer CPU storage requirements, and the intensive computer time (time step down to seconds), the linkage of HSPF and hydraulic model such as FEQ or UNET will be used when the basin runoff is subject to backwater or tidal flow conditions.

HSPF MODEL OF ST. LUCIE BASIN

Segmentation

The St. Lucie Basin is divided into six primary drainage basins: C-24, C-23, C-44, North Fork, South Fork Tidal, and four minor basins (Basins 4,5,6, and S-153). These are further divided into several secondary sub-basins. The basin was also divided into eleven precipitation segments using Thiessen polygons centering on the chosen rain gages (**Figure C-2**). However, due to missing data, concerns of computer storage capacity (31 years of hourly input and output for six land use types and hourly time step), the available project timeline etc. A simplified approach using average rainfall for each basin was applied and will be presented in detail later.

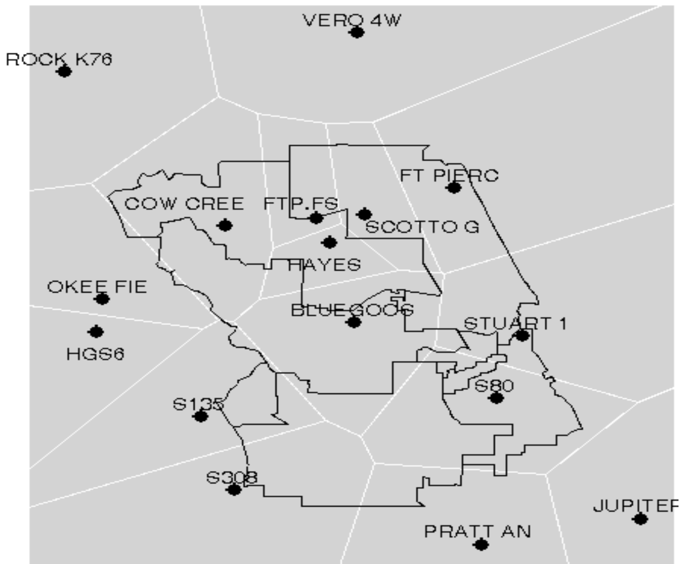

Figure C-2. Thiessen Map of the St. Lucie Estuary Watershed.

Land Use

The subbasin was further segmented by land use, which is one of the most important factors determining hydrologic response. Different treatment and/or characteristics of the soil are reflected in different hydrologic parameters. The 1988 land use conditions from the SFWMD Land Use and Land Cover GIS database were updated to 1994 land used by the Coastal Environmental, Inc. under District's contract. The following classifications were aggregated into five general categories for HSPF simulation:

Urban: residential, institutional, commercial, industrial, transportation, open & other

Groves: groves, cane, truck farms, rice, ornamental, nurseries, tropical fruits, feedlot

Pasture: improved/unimproved pasture, barren, rangeland

Forest: forest

Wetland: forested and non-forested wetlands

The Urban category is further divided into 60% pervious and 40% impervious. The impervious urban land is simulated using the IMPLND module of HSPF, while the pervious urban category is simulated using the PERLND module. A complete set of one IMPLND and five PERLNDs is used for each of the eleven precipitation segments. However, the precipitation segment was reduced into one segment for each basin to reduce computer storage requirement. **Table C-1** presents the land use by secondary Sub-basins for each major canal basin.

Table C-11. Land Use by Secondary Subbasin (unit in acres).

Basin	Sub	Urban-Imp	Urban-Per	Groves	Pasture	Forest	Wetland	Total
C-23	1	13	19	5	185	35	10	269
C-23	2	48	72	790	840	66	153	1,970
C-23	3	167	251	0	0	0	2	420
C-23	4	32	47	0	0	0	778	857
C-23	5	318	478	0	47	6	191	1,040
C-23	6	168	251	0	0	69	176	665
C-23	7	121	181	0	0	112	664	1,079
C-23	8	48	72	657	9	129	69	985
C-23	9	0	0	1,075	25	0	16	1,116
C-23	10	9	13	2,728	39	0	322	3,111
C-23	11	0	0	3,275	0	0	108	3,384
C-23	12	0	0	3,007	0	0	40	3,047
C-23	15	0	0	0	4,626	40	895	5,562
C-23	16	0	0	0	676	0	123	800
C-23	17	0	0	0	5,639	45	1,504	7,188
C-23	21	0	0	0	1,497	0	173	1,670
C-23	22	49	73	120	410	133	16	800
C-23	23	0	0	1,309	1,970	2	626	3,906
C-23	24	4	6	975	4	0	282	1,270
C-23	25	7	10	608	299	0	519	1,442
C-23	26	0	0	138	500	0	459	1,097
C-23	27	10	15	65	5,746	565	1,017	7,419
C-23	28	6	8	225	1,500	423	214	2,376
C-23	29	10	15	53	1,241	334	17	2,190
C-23	30	0	1	528	292	0	137	959
C-23	31	1	1	579	242	30	788	1,641
C-23	32	0	0	546	186	33	21	787
C-23	33	0	0	0	293	78	70	440
C-23	34	0	0	0	474	115	145	734
C-23	35	60	90	1,627	628	79	261	2,745
C-23	36	0	0	34	255	120	147	556
C-23	37	0	0	75	488	533	429	1,526

Basin	Sub	Urban-Imp	Urban-Per	Groves	Pasture	Forest	Wetland	Total
C-23	38	0	0	0	341	0	206	547
C-23	39	38	57	138	828	99	222	1,382
C-23	40	3	4	1,022	8,429	1,604	1,521	12,582
C-23	41	0	0	618	0	0	42	660
C-23	42	0	0	1,511	0	0	16	1,526
C-23	43	29	43	2,160	233	46	49	2,560
C-23	44	0	0	288	0	0	0	288
C-23	45	0	0	414	0	0	0	414
C-23	46	0	0	291	0	0	0	291
C-23	47	0	0	181	0	0	0	181
C-23	48	0	0	350	0	0	0	350
C-23	49	0	0	1,161	0	0	0	1,161
C-23	50	0	0	1,009	0	1	4	1,015
C-23	51	0	0	1,265	5	2	379	1,650
C-23	52	0	0	4,149	50	55	45	4,298
C-23	53	73	109	789	8,216	633	7,099	16,919
C-23	C8	40	60	9	0	0	0	345
C-23	C9	6	8	0	760	0	888	1,662
C-23	C10	0	0	1	155	0	233	389
C-23	K5	15	22	298	0	0	0	335
C-23 Total		1,273	1,909	34,076	47,127	5,387	21,078	111,606
SouthFork	1	313	469	0	0	3	1	786
SouthFork	2	398	597	8	15	162	25	1,206
SouthFork	3	233	349	13	0	203	55	854
SouthFork	4	738	1,108	91	76	476	844	3,332
SouthFork	5	68	101	0	0	26	121	316
SouthFork	6	156	234	50	103	22	692	1,256
SouthFork	7	23	35	0	0	0	3	61
SouthFork	8	13	19	0	0	0	0	32
SouthFork	9	34	50	0	0	12	2	98
SouthFork	10	388	582	696	157	271	1,431	3,525
SouthFork	11	701	1,051	3,063	11,998	1,548	8,014	26,375
SouthFork	12	404	606	209	486	599	281	2,585
SouthFork	14	170	254	829	594	388	117	2,352
SouthFork	15	34	52	357	765	135	13	1,357
SouthFork	16	0	0	478	32	136	0	646
SouthFork	x17	256	385	615	480	568	453	2,757
SouthFork Total		3,928	5,892	6,409	14,706	4,548	12,053	47,537

Basin	Sub	Urban-Imp	Urban-Per	Groves	Pasture	Forest	Wetland	Total
Basin4	1	427	641	0	45	73	109	1,296
Basin4	2	195	0	0	0	9	6	503
Basin4	3	122	183	0	0	77	98	479
Basin4	4	160	240	59	81	92	180	812
Basin4	5	174	261	0	34	52	28	550
Basin4	6	44	66	0	18	14	11	153
Basin4	7	66	100	0	5	261	0	431
Basin4	8	18	27	96	269	90	1	501
Basin4	9	3	4	0	314	260	1	581
Basin4	10	1	2	0	81	307	3	395
Basin4	11	0	0	2	518	236	119	874
Basin4	12	0	0	21	27	9	0	56
Basin4	13	50	75	25	0	36	1	188
Basin4	14	5	8	11	4	21	0	48
Basin4	15	31	46	0	0	44	0	121
Basin4	16	6	9	0	2	21	0	38
Basin4	17	14	21	0	0	68	0	103
Basin4	18	4	6	0	22	94	0	126
Basin4	19	7	11	0	18	24	1	61
Basin4	20	9	13	0	64	39	3	128
Basin4	21	0	0	0	21	9	1	30
Basin4	22	17	25	0	50	23	0	115
Basin4	23	74	111	0	23	53	317	577
Basin4	24	11	17	5	85	82	6	207
Basin4	25	2	3	0	6	176	393	580
Basin4 Total		1,441	1,870	220	1,687	2,165	1,278	8,953
Basin5	1	27	40	9	9	57	1	144
Basin5	2	22	33	5	4	4	0	68
Basin5	3	157	236	6	29	190	129	747
Basin5 Total		206	309	21	42	251	131	959
Basin6	1	100	150	21	2	170	2	446
Basin6	2	127	190	3	172	42	98	632
Basin6	3	21	31	0	127	1	1	180
Basin6	4	24	35	0	32	39	5	135
Basin6	5	4	5	0	61	4	0	74
Basin6	6	16	24	0	0	47	0	87

Basin	Sub	Urban-Imp	Urban-Per	Groves	Pasture	Forest	Wetland	Total
Basin6	7	7	11	32	0	13	0	62
Basin6	8	28	42	39	26	20	0	155
Basin6	9	12	17	0	0	31	0	60
Basin6	10	39	58	44	44	28	0	212
Basin6	11	120	181	24	145	267	112	849
Basin6	12	23	35	10	30	25	0	123
Basin6	13	50	75	0	32	0	0	157
Basin6	14	79	118	10	11	83	0	301
Basin6	15	186	278	0	120	115	11	710
Basin6	16	29	43	0	1	190	394	658
Basin6 Total		863	1,295	183	801	1,075	624	4,840
NorthFork	A1	1,399	2,098	0	0	368	2,355	6,220
NorthFork	A2	3,125	4,688	0	0	319	337	8,469
NorthFork	B1	2,015	3,022	1	10	987	3,277	9,312
NorthFork	B2	0	0	0	0	44	0	45
NorthFork	B3	5	8	15	0	26	0	55
NorthFork	C1	1,321	1,981	0	4	42	126	3,474
NorthFork	C2	891	1,336	0	0	1	282	2,509
NorthFork	C3	801	1,201	0	0	0	153	2,155
NorthFork	D1	417	626	9	3	403	278	1,736
NorthFork	D2	387	580	0	0	319	580	1,866
NorthFork	D3	113	170	0	0	7	14	304
NorthFork	D4	8	12	0	0	1	0	20
NorthFork	E1	82	123	144	7	175	228	759
NorthFork	E2	381	571	246	53	303	208	1,761
NorthFork	F1	2,653	3,980	0	0	215	614	7,462
NorthFork	F2	453	680	0	767	1,441	216	3,558
NorthFork	G1	488	733	76	433	710	545	2,984
NorthFork	G2	1,056	1,584	138	357	1,482	473	5,090
NorthFork	H1	186	280	55	2	130	92	744
NorthFork	H2	134	201	64	114	92	54	660
NorthFork	I	208	313	44	558	314	344	1,781
NorthFork	J	185	278	291	329	230	459	1,771
NorthFork	K	170	255	0	0	46	43	513
NorthFork	L	176	265	0	13	105	6	565
NorthFork	M	4	6	0	37	10	67	124
NorthFork	N	17	26	12	30	18	78	183
NorthFork	O	25	37	22	6	0	50	139

Basin	Sub	Urban-Imp	Urban-Per	Groves	Pasture	Forest	Wetland	Total
NorthFork	P	25	38	105	10	63	174	414
NorthFork	Q	38	56	94	21	29	100	338
NorthFork	R	14	21	408	144	15	149	752
NorthFork	S	347	520	1,645	655	1,172	392	4,730
NorthFork	T	26	38	237	67	162	18	548
NorthFork	U	85	127	2,074	411	462	1,336	4,494
NorthFork	V	21	31	6,724	68	13	129	6,984
NorthFork	W1	53	80	580	353	168	1	1,235
NorthFork	W2	60	90	475	489	104	17	1,236
NorthFork	W3	82	123	2,738	128	118	44	3,232
NorthFork	W4	8	12	1,083	11	13	0	1,127
NorthFork	W5	1	1	607	8	0	29	645
NorthFork	W6	4	6	2,059	22	3	5	2,098
NorthFork	W7	0	0	1,836	143	0	109	2,088
NorthFork	W8	1	2	2,255	9	0	148	2,416
NorthFork	W9	0	0	2,086	6	8	0	2,101
NorthFork	X1	254	382	56	0	44	0	736
NorthFork	X2	201	301	0	0	40	0	542
NorthFork	X3	98	146	103	5	55	20	427
NorthFork	X4	197	296	175	12	33	2	715
NorthFork	X5	168	252	226	98	199	9	952
NorthFork	X6	148	222	340	28	255	37	1,031
NorthFork	X7	99	148	193	37	156	5	639
NorthFork	X8	41	62	0	0	0	0	103
NorthFork	X9	245	368	103	0	145	25	887
NorthFork Total		18,916	28,373	27,317	5,448	11,047	13,630	104,731
C-24	A	372	559	0	0	42	100	1,073
C-24	B	120	180	0	0	1	38	339
C-24	C1	47	70	908	917	71	545	2,559
C-24	C2	2	3	199	654	160	748	1,767
C-24	C3	15	22	1,483	3	48	132	1,703
C-24	C4	2	3	960	29	1	21	1,015
C-24	C5	10	15	294	530	14	92	956
C-24	C6	0	0	152	123	2	9	286
C-24	C7	20	30	9	457	104	230	849
C-24	D	340	510	348	0	1,904	80	3,183
C-24	E	0	0	294	2	0	24	320
C-24	F	2	3	366	0	0	11	381
C-24	G	0	0	610	0	26	333	968

Basin	Sub	Urban-Imp	Urban-Per	Groves	Pasture	Forest	Wetland	Total
C-24	H1	3	5	199	2,650	569	354	3,780
C-24	H2	0	0	0	388	207	22	617
C-24	I	0	0	259	12	0	20	291
C-24	J	0	0	82	191	2	104	379
C-24	K1	5	8	1,287	144	33	6	1,484
C-24	K2	0	0	6	309	25	0	340
C-24	K3	26	38	316	424	130	78	1,011
C-24	K4	0	0	7	353	0	23	383
C-24	K6	0	0	630	10	0	0	640
C-24	K7	1	1	9	429	3	50	494
C-24	K8	0	0	96	3	0	0	99
C-24	L	115	172	1,948	1,935	184	159	4,512
C-24	M	0	0	236	0	0	64	299
C-24	N	0	0	310	12	0	0	322
C-24	O	0	0	36	1,302	190	106	1,633
C-24	P1	0	0	978	1,095	96	43	2,212
C-24	P2	0	0	320	0	0	0	320
C-24	P3	0	0	8	3,315	3	532	3,858
C-24	P4	0	0	955	5	0	4	964
C-24	P5	0	0	290	13	0	33	336
C-24	P6	0	0	1,025	31	87	146	1,289
C-24	P7	0	0	0	614	0	26	641
C-24	P8	0	0	641	492	0	741	1,874
C-24	P9	0	0	0	661	9	178	848
C-24	P10	0	0	609	5	1	34	649
C-24	Q	0	0	15	1,253	58	33	1,359
C-24	R	0	0	933	4	19	1	958
C-24	S	0	0	826	0	6	11	842
C-24	T	0	0	268	0	3	4	275
C-24	U	89	133	2,126	23,302	2,969	13,455	42,072
C-24	V	0	0	282	152	3	0	437
C-24 Total		1,169	1,753	20,318	41,818	6,968	18,590	90,617
S153	S-153	447	671	2,069	4,129	1,428	4,175	12,920
S153 Total		447	671	2,069	4,129	1,428	4,175	12,920
C-44	1	0	0	198	1,584	156	46	1,984
C-44	2	0	0	12	1,976	170	1,852	4,010
C-44	3	80	120	748	1,004	265	1,248	3,464

Basin	Sub	Urban-Imp	Urban-Per	Groves	Pasture	Forest	Wetland	Total
C-44	4	72	107	3,993	2,628	397	2,085	9,281
C-44	5	17	25	705	814	23	16	1,600
C-44	6	0	0	2,955	0	194	12	3,161
C-44	7	0	0	1,586	1,062	95	327	3,071
C-44	8	38	57	215	1,512	0	319	2,141
C-44	9	0	0	1,886	8	76	0	1,971
C-44	10	16	23	656	1,210	393	807	3,104
C-44	11	1	2	819	0	60	0	881
C-44	12	3	4	1,718	385	0	1,484	3,594
C-44	13	0	0	7,808	248	140	726	8,921
C-44	14	231	346	6,866	4,875	1,112	998	14,428
C-44	15	34	51	0	9	245	2	341
C-44	16	303	454	933	918	744	272	3,625
C-44	17	12	18	4,781	478	91	3,290	8,670
C-44	18	6	9	859	4	24	0	902
C-44	19	2	4	3,254	0	279	5	3,545
C-44	20	0	0	2,020	0	499	0	2,520
C-44	21	74	111	476	84	30	167	940
C-44	22	0	0	1,223	196	0	4	1,423
C-44	23	100	150	931	0	216	445	1,841
C-44	24	267	401	1,828	186	167	2,007	4,856
C-44	25	2	3	0	0	0	1,609	1,614
C-44	26	16	24	43	216	0	1,384	1,681
C-44	27	13	19	23	22	24	742	842
C-44	28	0	0	11	0	81	117	210
C-44	29	28	42	1,038	0	390	0	1,498
C-44	30	395	592	405	51	439	7,377	9,259
C-44	31	17	26	881	5,905	1,180	2,708	10,717
C-44 Total		1,724	2,587	48,873	25,372	7,490	30,049	116,095
Grand Total		29,968	44,659	139,486	141,131	40,359	101,607	498,258

Rainfall

The **Table C-2** presents a summary of rainfall data for St. Lucie Basin simulations.

Table C-2. Summary of Rainfall Data for St. Lucie Basin Simulations

ID. NO.	Station Name	Period of record
Daily Rainfall Stations:		
NOAA -6032	Ft. Pierce	1962-1995
MRF-39	Scotto Groves	1962-1995
MRF-37	Ft. Pierce Field Station	1971-1995
MRF-148	Cow Creek Ranch	1971-1995
MRF-40	Hayes Property	1971-1995
MRF-241	Bluegoose	1979-1995
NOAA-6082	Stuart 1N	1957-1995
MRF-7035	S80(NOAA-7859)	1957-1995
MRF-54	Pratt and Whitney	1957-1995
MRF-7037	S308(NOAA-7293)	1957-1995
MRF-150	S-153	1972-1995
Hourly Stations:		
MRF-40	Hayes Property	1971-1995
MRF-148	Cow Creek Ranch	1970-1995
MRF-241	Bluegoose	1979-1995
MRF-7035	S80(NOAA-7859)	1965-1994
MRF7037	S308(NOAA-7293)	1965-1994
NOAA-9219	Vero Beach 4W	1965-1995

The rainfall data was extracted from SFWMD's DBHYDRO database. Missing data were filled from adjacent stations. The accumulated data were interpreted from the adjacent stations with the estimated data adjusted by the ratio of rainfall amount into daily value and still keep the accumulated amount the same.

Six of the hourly stations within and near the basin have periods of record from 1965-1995 as shown in **Table C-2**. These stations were used to desegregate the daily data for each basin to produce hourly data for use in the HSPF simulations, covering the period 1965-1995.

Table C-3 presents rainfall stations and weighing factors used for each basin in the St. Lucie Basin.

Table C-3. Rainfall Stations and Weighing Factors Used for each Basin .

BASIN	RAINFALL STA.	WEIGHING	PERIOD
C-23	MRF148	0.30	1972-1978
	MRF40	0.25	
	MRF44	0.10	
	MRF150	0.15	

	MRF7035	0.20	
	MRF148	0.30	1979-1995
	MRF241	0.40	
	MRF44	0.10	
	MRF150	0.10	
	MRF7035	0.10	
C-24	MRF148	0.3333	1971-1978
	MRF40	0.3333	
	MRF37	0.3333	
	MRF148	0.25	1979-1995
	MRF40	0.25	
	MRF37	0.25	
	MRF241	0.25	
BASIN	RAINFALL STA.	WEIGHING	PERIOD
C-44	MRF7035	0.40	1957-1971
	MRF7037	0.40	
	MRF54	0.20	
	MRF150	0.15	1972-1995
	MRF7035	0.35	
	MRF7037	0.35	
	MRF54	0.15	
North Fork	MRF6032	0.40	1965-1995
	MRF39	0.25	
	MRF37	0.15	
	MRF6082	0.20	
Ten Mile Creek	MRF6032	0.50	1965-1995
	MRF39	0.50	
S-153	MRF7037	1.00	1965-1970
	MRF150	1.00	1971-1995
South Fork Tidal	MRF6082	0.20	1965-1995
	MRF7035	0.70	
	MRF54	0.10	

Evaporation

Daily evaporation data are available at three locations within or near the watershed: Ft. Pierce Experimental Station, Belle Glade Experimental Station, and Hurricane Gate Structure (HGS) 6. The potential ET record at Ft. Pierce Station is the primarily data used in the model. Missing data in this station were filled using the other two stations. The model uses pan coefficient to derive an estimate of potential ET (PET). Actual (simulated) evapotranspiration is based on three general factors: the model algorithms, the ET parameters, and the input PET. As a results from the model calibration process based on Chemicals, Runoff, and Erosion From Agricultural Management System with Water Table (CREAMS-WT) model applied to C-23, C-24 basins, the pan coefficient of 0.60 was chosen for C-24 basin and 0.64 for C-23 and rest of the watershed.

Soils, Slopes, and Elevation

The District's GIS database contains land use/clover, soil types, topography, and hydrography etc. The soil properties database contains hydrologic soil group, permeability, porosity (maximum/minimum available water capacity), and erosion factor. The data are generally available for two depth horizons (0 to 20 inches and 20 to about 60 inches). However, some secondary basins do not have soil data due to owners' access restriction to their properties. These data were used to estimate the range and the variability of porosities, infiltration rates, and soil storage parameters in PERLND module.

Land slopes are not generally used in the HSPF12.0; however, average elevations for each segment were estimated from the USGS 7.5 minute quad maps (the data with topography data of early 1980 for Ten Mile Creek basin, portions of Eastern Martin County were available from the District's GIS database).

Supplemental Irrigation

One of the major environmental concerns in the St. Lucie Estuary and Indian River Lagoon is the timing and distribution of freshwater inputs as results from post project conditions. The present fresh water flow pattern has been characterized as the follows:

The exaggerated low flows during the dry season months

The reduction or lack of flush from spring rainfall due to irrigation for agricultural activities

An excess quantity of fresh water received during the wet season for crop and residential flood protection

An increased drainage capacity than pre-project conditions

The canal system primarily serves as a source of agricultural irrigation water and a mean to control water table levels to maximize crop production and reduce flood damages. During the wet season, flows to the estuary often increase abruptly and result in much greater volumes of fresh water discharge to the estuary compared to the pre-development conditions. Conversely, fresh water during the dry season is in short supply and the canal system is controlled to retain and reuse fresh water for irrigation to the maximum extent possible. These activities greatly reduce dry season base flows that normally would enter the estuary under pre-project condition.

The site-specific data on irrigation application amounts, acreage, and timing were scarce. The water use permits did not provide sufficient information to be useful in the model simulation. The amounts of irrigation withdraw from surface water to mix with groundwater sources are not easily to estimate. The irrigation method and their acreage, in general, are available from the report prepared by the USDA Soil Conservation Service entitled, "Indian River Lagoon Agricultural Land-Use Inventory and Discharge Study, dated December 1993". The information were compiled by using AFSIRS (Agricultural Field Scale Irrigation Requirements Simulation developed by Smajstrla, 1990) to develop 31-year of daily irrigation demands and irrigation supply for North Fork, C-44 basins. The results were compared (a calibration process) to the supplemental irrigation derived from the model calibrated results for C-23 and C-24 basins which will be discussed in the following paragraph.

The amounts of irrigation used by the citrus growers are based on the observed daily water level, daily flow at water control structures such as S-97 and S-49, and channel cross-section such as C-23 and C-24. The daily withdraw was estimated by the daily stage difference and the stage-area-volume relationship derived from the channel cross-section. This volume of water was then divided by the total irrigated area to come up with irrigation amount in inches per day for 31 years. This amount was than increased by 40 % (derived from the Upper East Coast Regional Water Supply Plan developed in 1998) to cover the additional water withdraw from deep groundwater source. A time series of total daily irrigation withdraw (both from surface and deep groundwater sources) for 31 years was developed, and applied in the HSPF model calibration runs. These time series were adjusted as additional precipitation for citrus groves within the basin. This data set was further adjusted based on the calibration of discharge through structure and water level agreements between computed and observed data at the structure.

HSPF UCI FILES

A single User's Control Input (UCI) file, which simulates the runoff from land area within the St. Lucie Estuary Watershed, was set up for each basin. The UCI breaks down the basin primarily by precipitation segment, rather than by secondary basin boundaries. In each of the eleven precipitation segments, there are five land use categories represented by five PERLND operations plus one IMPLND operation, which models the impervious fraction of the urban category. These operation produce per-acre water yield (runoff) for each land segment. The outflows are multiplied by the corresponding acreage in the SECHEMATIC block and accumulated by the COPY operations to give the total runoff for each basin. The times series of runoff, hourly rainfall, daily evaporation, irrigation supply and withdraw are stored in the HECDSS data file.

Tables C-4 and **C-5** present a list of parameters used in the St. Lucie Watershed with calibration values. Wetlands are assumed to lie at a lower mean elevation (MELEV), resulting in a lower zone nominal storage, and the interflow parameter (INTFW) is set to zero and the interflow recession constant (IRC) is set equal to baseflow recession (**Table C-5**).

Table C-4. Land use-specific Hydrology Parameters used in HSPF St. Lucie Watershed

Parameter	Urban/Pasture	Groves	Forests	Wetlands
INFILT (in/hr)	0.08	0.10	0.12	0.04
CEPSC (in)	0.10	0.14	0.10	0.10
UZSN (in)	0.30	0.60	0.60	0.20

LZSN (in)	3.00	3.00	3.00	2.50
LZETP	0.30	0.45	0.50	0.45

Note: INFILT is the infiltration, CEPSC is the interception storage capacity, UZSN is the upper zone nominal storage, LZSN is the lower zone nominal storage, and LZETP is the lower zone ET.

Table C-5. Wetland Hydrology Parameters

Parameter	Urban/Pasture	Groves	Forests	Wetlands
RTOPFG	2	2	2	3
INTFW	1.00	1.00	1.00	0.00
IRC (/day)	0.90	0.95	0.90	0.99
MELEV	27.00	27.00	27.00	24.70
STABNO	-	-	-	1
SRRC (/hour)	0.90	0.90	0.90	-
SREXP	1.00	1.00	1.00	-
IFWSC (in)	1.00	1.00	1.00	1.00

Note:

RTOPFG is flag value for selecting the algorithm for computing surface runoff from the wetland category. If RTOPFG is 1, routing of overland flow is done in the same way as in the predecessor models HSPX, ARM and NPS. A value of 2 results in use of a simple power unction method. If a value of 3 is entered, the program uses a table in the FTABLES block to determine surface outflow as a function of surface storage. The parameter STABNO gives the ID number to be found in the FTABLES block of the UCI file. If STABNO is 1 for the wetlands means FUNCTION TABLE 1 is used for runoff from the wetland. SRRC and SREXP are recession constant and exponent to relate surface runoff to surface storage.

RCHRES MODULE

RCHRES was used in the C-23 and C-24 basins if daily flow daily stage data and channel cross-section are available. These data will help to better define the storage system available in the existing basin. If there is no measured historical data for model calibration, the RCHRES is not used and the black box approach is used for that basin.

Numerous pumps and culverts connect the project canal with the secondary drainage ditches in the land adjacent to the canal. Citrus areas represent the most intensive drainage network for their flood protection and water supply needs. Pumps are most common for the citrus lands and in general the drainage capacity was designed to remove 2 inches per day of runoff from their lands. The following assumptions were made for the secondary and tertiary canal system due to lack of field data:

The secondary drainage canal for a typical citrus land:

Cross section: 35 feet bottom width at elevation at 18.0 FT.NGVD.

Side Slope: 1V (Vertical) on 2H (Horizontal).

Total channel length per square mile area: 3 miles.

Lowest bottom elevation: 14 feet NGVD.

The tertiary canal for a typical citrus land :

Cross section: 10 feet bottom width with elevation at 20.0 Ft. NGVD.

Side slope: 1V on 2 H.

Total channel length per square mile area: 10 miles.

The secondary canal for non-grove lands :

Cross section: 20 feet bottom width with elevation at 19 Ft. NGVD.

Side slope: 1V on 2H.

The lowest bottom elevation: 14.0 ft. NGVD.

Total channel length per square mile area: 1 mile.

The tertiary canal network for non-citrus lands:

Cross section: 5 feet bottom width with elevation at 21 ft. NGVD.

Side slope: 1V on 5H with depth.

Total channel length per square mile area: 2 miles.

F-table was then developed for both citrus and non-grove lands. The flow rates were adjusted during calibration processes based on simulation of 31+ years of daily data at S-49 and S-97.

The basin such as C-23 and C-24 was divided into three RCHRES. All citrus PERLND elements are discharged into RCHRES with F-table developed for that land use, and another RCHRES for non-grove lands. Both RCHRES were routed through the most downstream RCHRES, which is the project canal, before discharging into the estuary. The F-table for the project canal was developed based on the most recent surveyed cross-sectional data available for C-23 and C-24 canals. Additional RCHRES can be incorporated into the model when additional secondary channel data become available.

CALIBRATION AND MODEL RESULTS

Calibration was performed on the C-24 Canal basin for the years from 1980 to 1992 by Aqua Terra Consultants and Linsley, Kraeger Associates in 1997. The simulated outflow was compared directly with the observed flow values. Several factors were discussed and were considered as problematic. These factors are further investigated and improved by the District staff during 1998. The district's continuing efforts are described in the following paragraphs.

Problematic 1

The application amounts and timing of irrigation as well as their sources are not available. A method of estimating the irrigation applied to groves was developed and relies on several assumptions regarding irrigation method and irrigation and rainfall efficiency in meeting the demand. This approach as presented in the 1997 report was not considered satisfactory. This was the reason that daily stage, flow, and channel data were used to estimate irrigation withdraw from project canal and adjusted by an assumption of additional 40% water from deep groundwater as described in the irrigation section of this report.

Problematic 2

The discharge rating curves for S-49 used in the calibration runs were updated using twelve flow measurements and the missing data or data had not processed were recomputed by the District's Data Management Division. However, the quality of flow data for S-49 and S-97 are considered as fair. **Tables C-6** and **C-7** present the monthly runoff Coefficients based on the ratio of observed runoff and rainfall over C-23, and C-24 basins. The runoff coefficients exceed 50% are considered not reliable. **Tables C-6** and **C-7** indicate there are over 20 % of the monthly data can be considered not reliable. However, this is the best available data in which nothing further can be done to improve the quality of the data.

Table C-6. Monthly Runoff Coefficeints for C-24 Basin Based on Observed Runoff Rainfall Ratio.

Sum of RO	MONTH												
YEAR	1	2	3	4	5	6	7	8	9	10	11	12	Grand Total
1965	0.00	9.03	4.04	0.00	0.00	0.00	7.68	1.95	15.38	18.22	28.11	1.87	86.27
1966	36.55	41.01	31.48	2.23	14.59	22.87	36.69	54.18	15.40	74.61	0.00	4.59	334.20
1967	0.00	7.57	0.00	0.00	0.00	12.40	13.25	1.07	38.50	22.79	11.58	0.00	107.16
1968	0.00	0.00	0.00	0.95	28.40	68.07	23.66	3.36	10.85	24.81	18.47	0.00	178.57
1969	75.72	25.20	41.49	81.00	16.91	23.56	15.40	90.98	65.64	52.05	93.48	94.29	675.71
1970	202.76	102.91	49.00	428.92	0.08	9.63	20.11	28.53	23.58	49.90	37.81	0.00	953.22
1971	0.00	4.55	48.85	0.00	0.15	9.32	36.40	31.06	58.97	42.17	101.07	9.89	342.42
1972	15.45	20.42	15.59	34.25	22.14	36.25	13.61	14.11	23.73	7.44	11.66	47.27	261.92
1973	25.51	39.39	17.23	19.96	6.06	23.00	26.05	35.37	51.51	62.66	870.40	10.58	1187.73
1974	0.00	0.00	0.00	0.00	0.00	14.16	54.60	77.05	27.09	45.09	15.22	18.73	251.93
1975	39.14	0.00	0.00	0.00	12.79	18.90	29.92	30.26	28.39	53.06	30.31	24.97	267.74
1976	18.76	4.27	58.63	19.59	22.03	59.93	35.42	18.68	25.45	52.18	3.13	19.98	338.06
1977	18.87	16.54	44.46	0.00	0.00	1.46	1.63	16.81	36.56	8.18	20.05	46.69	211.26
1978	35.73	26.24	32.48	4.15	6.26	14.06	19.34	34.64	14.13	22.46	14.52	18.24	242.24
1979	68.94	274.50	3.43	0.00	34.80	19.14	15.64	16.76	57.77	111.75	53.90	31.68	688.32
1980	8.64	22.15	8.25	24.86	5.72	5.29	7.25	4.79	29.88	0.00	0.80	2.20	119.82
1981	0.00	0.00	0.00	0.00	0.00	0.00	4.18	20.06	46.74	11.13	0.00	0.00	82.11
1982	0.00	4.91	30.32	49.07	42.67	78.28	77.81	62.27	61.20	69.76	34.85	28.90	540.04
1983	8.90	74.21	93.26	39.67	0.00	18.01	7.04	27.41	38.81	75.91	113.01	20.98	517.21
1984	231.50	24.42	23.19	10.32	7.92	9.98	36.82	34.51	34.22	78.61	34.14	186.73	712.35
1985	10.60	0.00	12.49	19.40	0.00	1.64	39.45	48.70	62.00	82.65	12.82	0.00	289.76
1986	12.79	0.00	6.32	0.00	0.00	24.40	39.81	70.62	31.37	18.75	47.79	4.61	256.46
1987	52.66	8.54	21.01	77.70	0.00	0.00	28.16	18.64	11.01	32.81	76.57	11.08	338.17
1988	5.50	30.47	17.65	0.00	15.26	7.64	22.24	35.44	35.19	0.00	0.00	0.00	169.39
1989	0.00	0.00	7.92	1.76	2.64	0.00	20.76	42.84	42.37	40.84	5.70	15.86	180.70
1990	72.87	18.28	19.44	0.00	0.00	8.57	36.48	35.76	46.04	150.42	23.97	0.00	411.82
1991	30.22	49.77	46.59	53.44	10.99	34.02	83.43	61.97	35.46	110.47	0.00	0.00	516.36
1992	0.00	0.44	0.00	0.00	0.00	28.73	71.65	51.07	56.72	65.78	29.01	21.04	324.42
1993	80.14	68.76	90.80	53.16	0.00	4.23	37.37	18.62	50.34	68.94	17.88	13.14	503.39
1994	27.06	78.64	34.69	7.76	26.29	74.75	30.46	54.97	55.48	61.78	61.80	83.76	597.45
1995	136.49	29.46	38.64	9.54	0.00	2.74	24.64	68.27	62.24	89.69	107.62	-0.12	569.21
Grand Tota	1214.80	981.69	797.24	937.73	275.71	631.06	916.91	1110.72	1192.02	1604.92	1875.65	716.95	12255.40

Table C-7. Monthly Runoff Coefficients for C-23 Basin Based on Observed Runoff Rainfall Ratio.

Sum of ro/rf-%	MONTH												
YEAR	1	2	3	4	5	6	7	8	9	10	11	12	Grand Total
1965	0.00	22.15	26.40	6.66	3.65	0.16	17.90	44.35	29.06	39.10	88.88	10.65	288.97
1966	49.27	56.93	23.53	5.46	8.19	20.03	141.61	54.51	26.54	53.77	19.27	3.14	462.26
1967	0.74	5.13	10.46	13.16	0.00	9.38	30.95	15.38	9.38	12.55	8.59	0.00	115.72
1968	0.00	0.00	0.00	0.00	9.94	45.66	79.22	32.48	6.49	20.78	21.58	0.00	216.15
1969	1.42	3.51	20.46	6.53	12.89	67.79	36.29	64.45	42.04	72.10	174.00	53.09	554.56
1970	55.36	26.77	22.49	3661.52	4.09	14.91	75.86	80.33	22.35	38.78	45.69	0.00	4048.15
1971	0.00	0.00	0.00	0.00	0.00	1.19	20.77	37.44	25.46	32.02	58.92	6.14	181.94
1972	1.03	5.02	6.28	25.51	13.09	53.94	9.33	23.36	5.00	0.51	0.03	0.00	143.10
1973	0.57	35.36	16.08	0.84	0.58	38.56	26.16	25.37	48.69	35.44	338.42	68.05	634.13
1974	0.00	0.00	0.00	0.00	0.13	9.34	30.29	75.71	61.26	24.89	0.00	0.36	201.98
1975	0.00	1.03	1.80	11.22	10.83	23.58	29.25	32.49	21.77	42.63	0.00	0.00	174.59
1976	0.00	0.00	0.00	0.00	31.83	54.20	12.32	18.40	18.04	0.00	2.99	18.53	156.31
1977	21.91	24.65	1.23	0.41	2.05	2.35	4.63	14.08	25.55	3.58	35.63	37.03	173.12
1978	45.81	34.71	42.32	11.30	2.98	13.27	15.38	26.56	24.35	24.82	30.18	8.16	279.84
1979	65.76	213.01	12.00	0.72	5.91	9.07	16.99	14.16	41.60	92.95	17.52	31.27	520.94
1980	9.02	36.02	10.85	11.46	0.56	1.77	9.31	20.21	47.77	2.95	11.30	8.71	169.92
1981	1.42	11.40	0.36	2.99	0.39	0.95	1.93	24.08	4.07	1.55	14.14	26.90	90.20
1982	2.89	15.16	23.79	28.34	19.40	37.00	36.83	42.42	40.65	34.96	18.30	16.23	315.97
1983	4.78	53.65	62.51	24.38	2.02	6.76	6.31	17.98	43.88	48.19	61.74	13.49	345.68
1984	104.50	16.50	26.47	18.37	9.13	13.19	18.15	25.27	26.56	86.82	37.56	109.10	491.61
1985	0.00	0.00	12.72	15.95	0.00	0.18	24.72	48.34	47.58	76.47	22.34	2.81	251.11
1986	29.86	10.88	10.53	0.00	6.25	36.54	44.20	53.86	59.18	23.58	21.20	19.40	315.48
1987	71.38	19.78	30.60	165.85	0.36	0.66	9.05	9.17	11.22	25.51	42.53	784.80	1170.92
1988	18.21	28.77	16.07	1.95	2.35	-3.24	6.19	7.57	29.97	5.58	8.39	-20.37	101.44
1989	7.41	-44.51	0.00	0.00	0.00	0.00	0.49	23.12	-4.77	-4.25	0.00	-7.75	-30.27
1990	0.00	0.00	0.00	0.00	-8.32	11.61	8.47	5.97	4.51	11.71	36.66	3.55	74.17
1991	21.55	-9.07	55.25	29.76	57.66	32.33	28.63	66.36	76.62	39.96	0.00	7.31	406.36
1992	0.00	0.50	0.00	0.00	0.00	17.80	57.76	54.24	51.41	108.44	59.75	79.97	429.87
1993	58.62	59.90	62.66	67.28	5.96	14.11	23.32	17.90	32.31	-2.99	14.32	6.81	360.20
1994	21.76	48.69	28.67	26.93	42.78	57.77	36.23	34.26	50.45	45.83	51.03	41.83	486.22
1995	23.47	15.24	26.47	0.02	0.00	4.16	23.11	59.72	56.29	82.32	35.82	0.00	326.62
Grand Total	616.71	691.16	549.99	4136.59	244.71	595.01	881.66	1069.54	985.30	1080.59	1276.79	1329.22	13457.27

		Missing				50-99%				>100%			

Problematic 3

There are many missing or data gaps for most of the hourly rainfall stations. The interior gages such as Cow Creek Ranch, Hayes Property, and Bluegoose tend to register a lower rainfall amounts (in average 12 to 17 inches per year). The efforts to verify and fill those missing gaps were performed during 1998.

The soil parameter values were first evaluated based on the assumption of no irrigation withdraw from local resources, and no RCHRES option in place. This Scenario is designated as Simulation 1(SIM1). Under this scenario if the monthly flow compared favorably with the observed monthly flow at S-49 and S-97, then the parameter values used in the model will be considered reasonable. The values in general are not much different from the values used by the Aqua Terra Consultants in their 1997 study except the upper and low influence elevations were slightly reduced.

Figures C-3 and **C-4** present the comparison of observed and simulated monthly flow at S97 under Scenario 1 (SIM1). In general, good agreement exists for wet season months and not as good for dry season. The simulated flow during dry season tends to be higher than the observed flow. This is reasonable because the irrigation and RCHRES option were not applied. The farmers conserve water for their irrigation needs during dry months and water was withdraw from the canal system, therefore less runoff is being released the main water control structures such as S-49 and S-97.

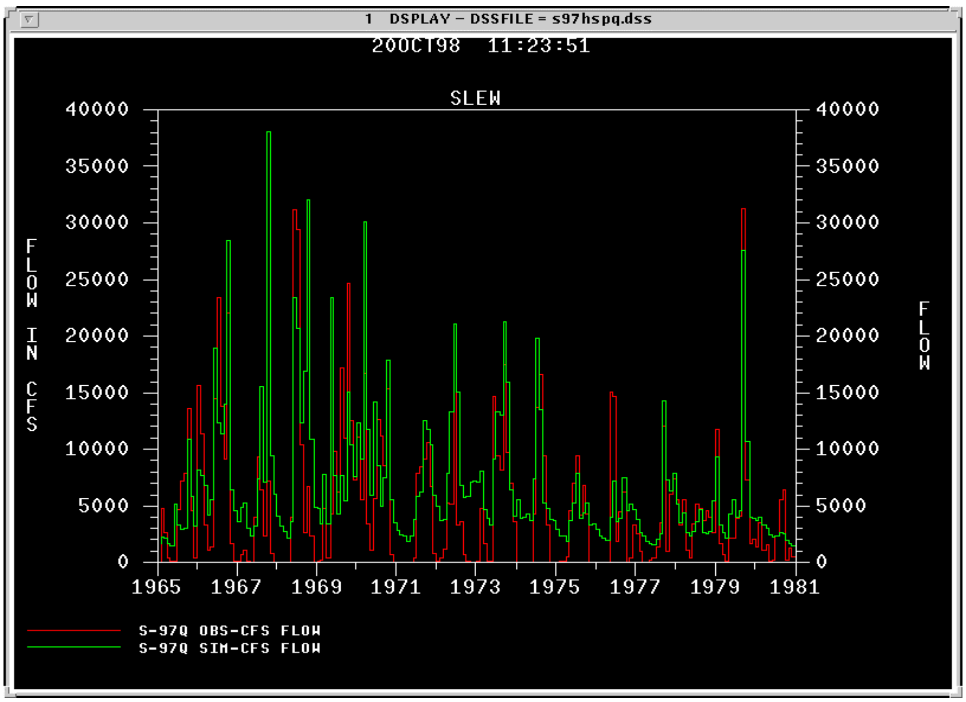

Figure C-3. Observed and Simulated Monthly Flow at S-97 without Irrigation Scheme (1965-1980).

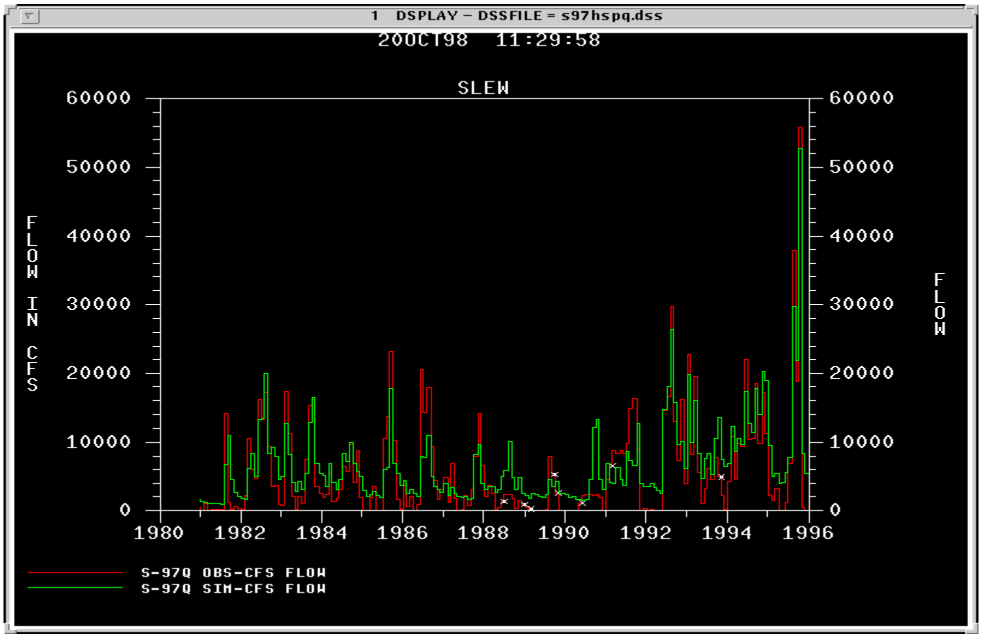

Figure C-4. Observed and Simulated Monthly Flow at S-97 without Irrigation Scheme (1981-1995).

Figures C-5 and **C-6** presents the comparison of observed and simulated monthly flow at S-97 under Scenario 2 (SIM2). Under this scenario, the supplemental irrigation and RCHRES option are included in the model run. The simulated results are much better for both wet and dry seasons. The irrigation withdraw from C-24 canal is not only used by the citrus growers within the C-24 basin. In fact, there are several irrigation pumps exist which are withdraw water from C-24 to irrigate the farms located within the North St. Lucie Water Control District. The amount of water and irrigated acreages are not available, therefore the estimation of total surface water irrigation for C-24 basin may be in the high side as indicated in the water budget presented for C-24 basin (Appendix B).

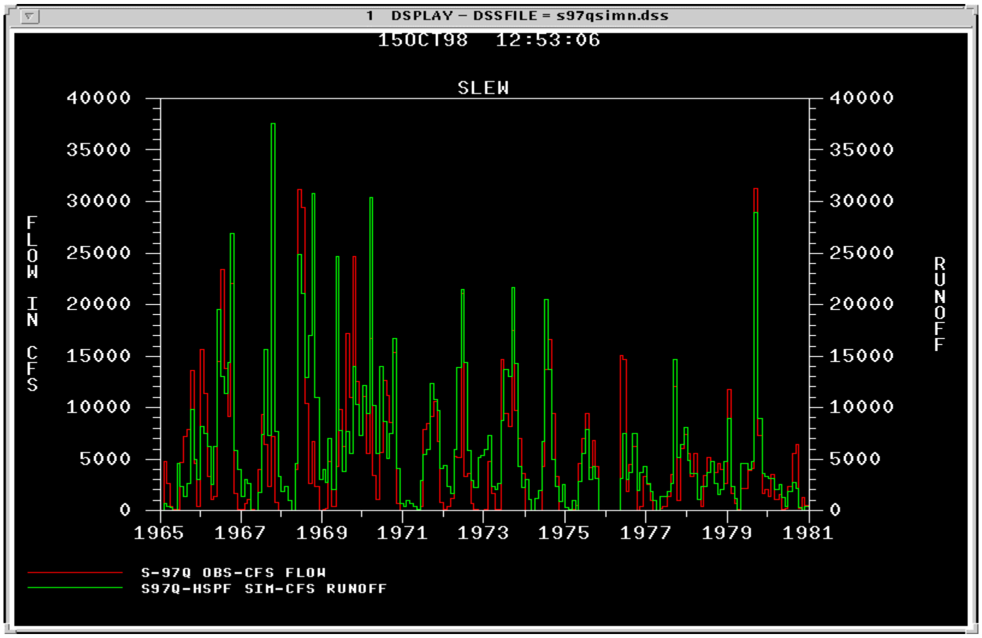

Figure C-5. Observed and Simulated Monthly Flow at S-97 with Irrigation Scheme (1965-1980).

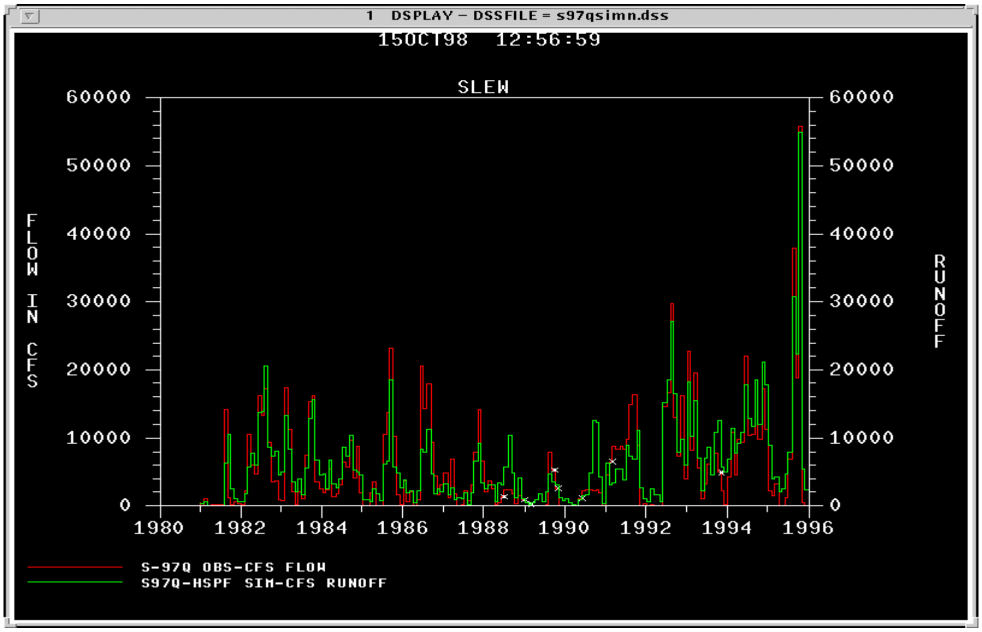

Figure C-6. Observed and Simulated Monthly Flow at S-97 with Irrigation Scheme (1981-1995).

A seasonal optimum stage was maintained in the project canal. For example, in C-23 Canal an optimum stage of 20.5 to 22.2 ft. NGVD for wet season from May 15 to October 15 are maintained, and 22.2 to 23.2 ft. NGVD for dry season from October 16 to May 14. However, this schedule was not followed exactly every year by the District's operation staff as they can be observed from **Figures C-7** through **C-9**, which present the comparison of daily observed and simulated stage at S-97. S-97 is an automatic gated structure with gate operation according to the incoming flow and water level at the upstream of the structure. From **Figures C-7** to **C-9**, one can observed that the daily flow went up and down rather quickly (gates opened and closed) due to rapid gate operations. This type of operation cannot be modelled correctly by the model. In the model the discharge releases was based on structure capacity limits, optimum stage, and amount of incoming runoff, the actual gate operation was not simulated. This may explain why the daily simulation tends to produce more of small flow than observed conditions in which gate close more frequent or larger opening.

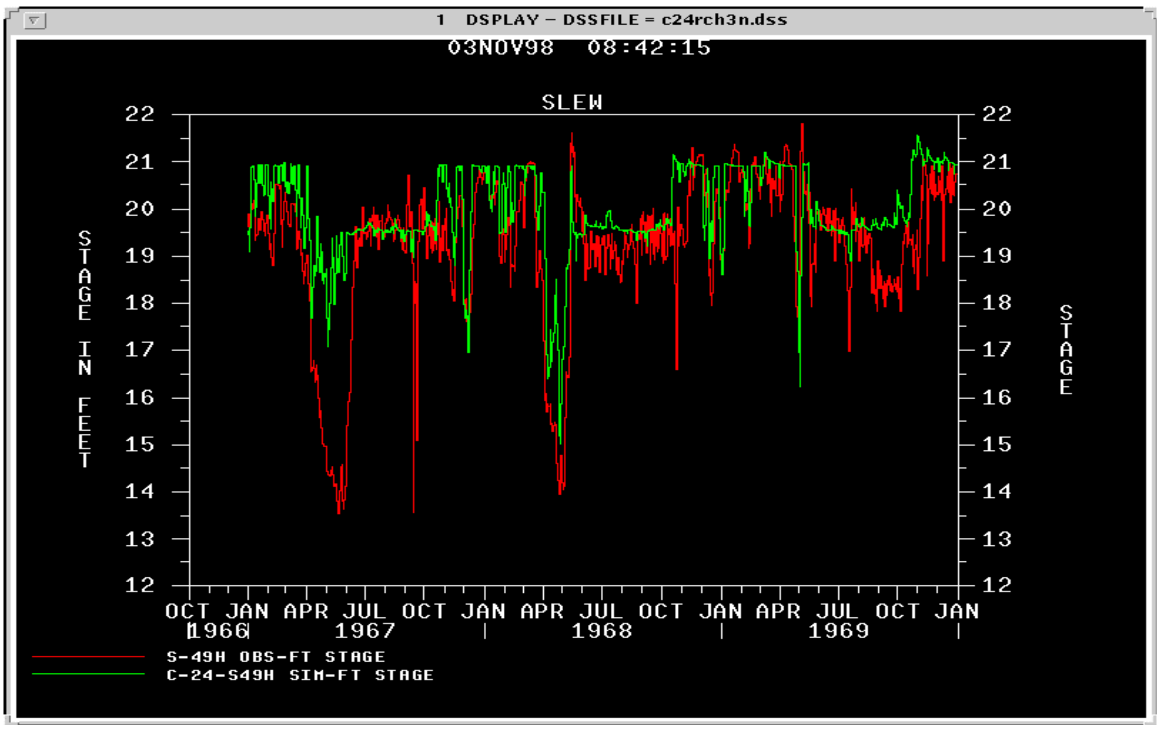

Figure C-7. Comparison of Observed and Simulated Daily Stage at S-49 (1966-1969).

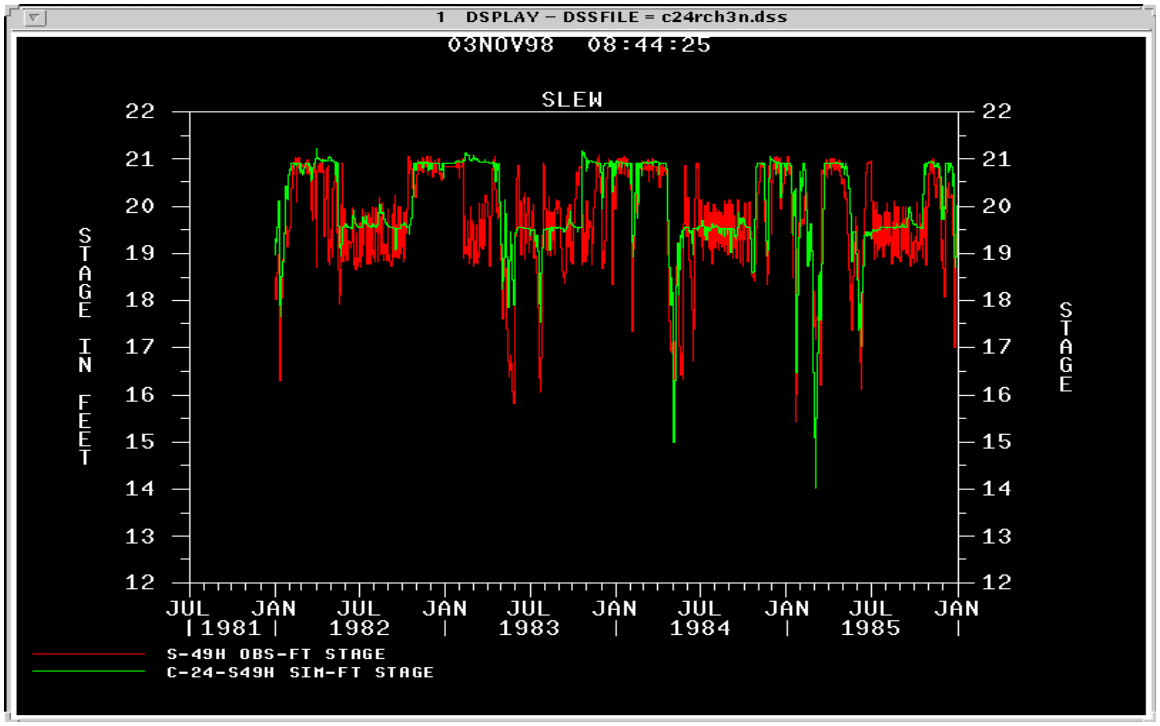

Figure C-8. Comparison of Observed and Simulated Daily Stage at S-49 (1981-1985).

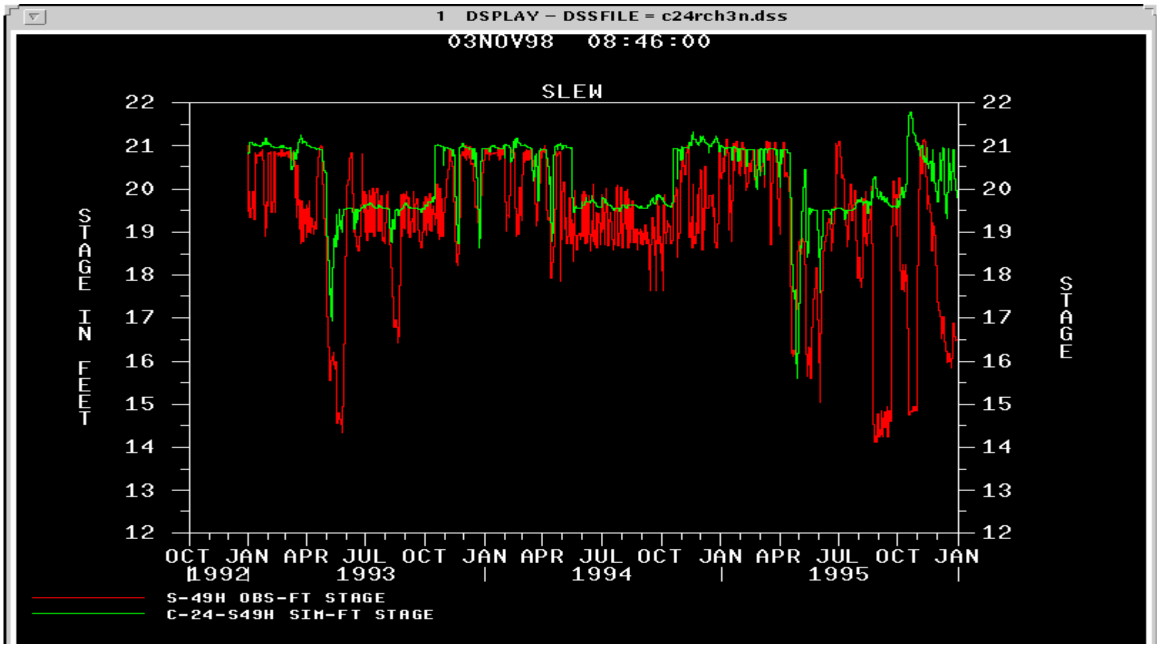

Figure C-9. Comparison of Observed and Simulated Stage at S-49 (1992-95).

Figure C-10 presents a comparison of observed and simulated monthly flow frequency curves at S-97. Both curves are fairly close except low flow conditions as explained early. Noted that there are several months of missing observed data at S-97.

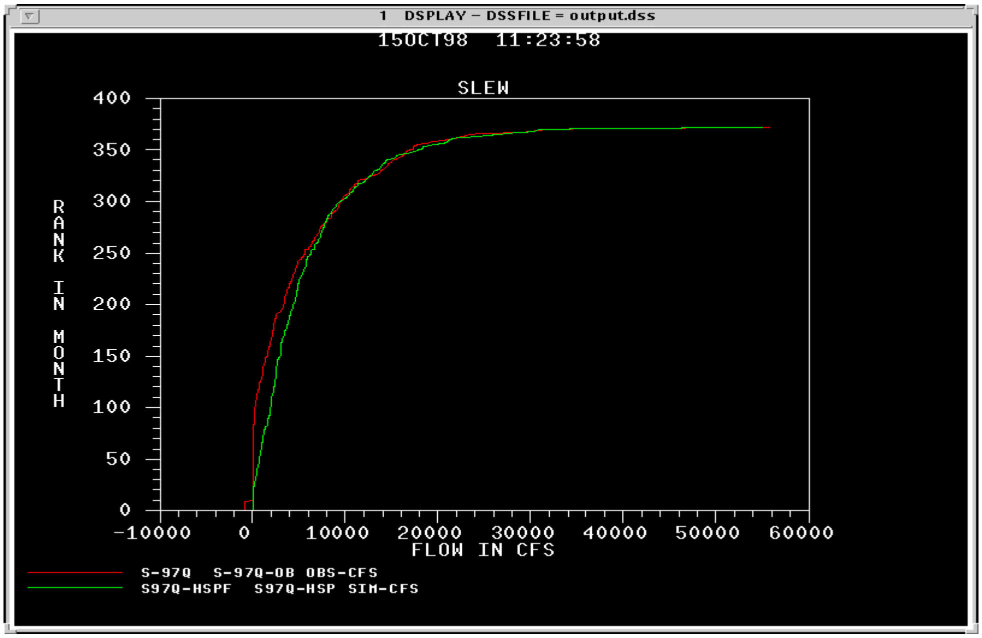

Figure C-10. Comparison of Observed and Simulated Monthly Flow Frequency Curves at S-97.

Figure C-11 presents the comparison of observed and simulated average monthly flow from C-23 basin under SIM1 and SIM2 scenarios. The simulated values tend to be slightly higher due to the assumption used for land uses. The land use of 1994 was used throughout the period from January 1965 through December 31, 1995 in which developed area has increased substantially since 1965. The simulation results may be improved further by better estimation of daily supplemental irrigation and groundwater withdraw based on seasonal demand, however, this improvement to the simulation results is considered not worth the additional efforts.

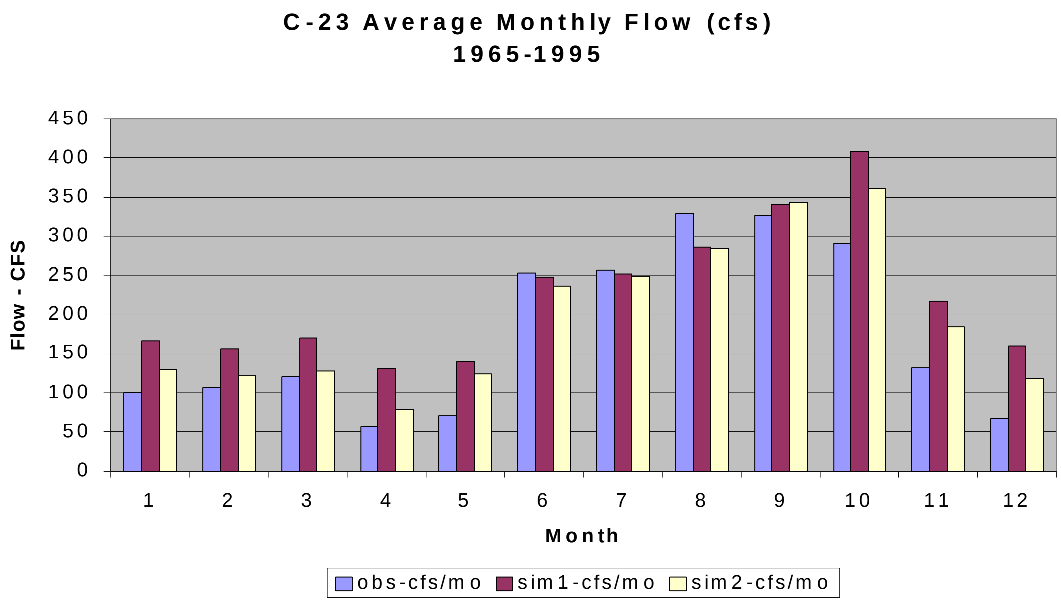

Figure C-11. Comparison of Observed and Simulated Average Monthly Flows from C-23 Basin.

Figures C-12 and **C-13** present comparison of observed and simulated monthly flow at S-49 (C-24 Basin) under SIM2 scenario for period from January 1965 through December 1995**. Figure C-14** presents a comparison of observed and simulated average monthly flow for C-24 basin. **Figure C-15** presents a comparison of observed and simulated monthly flow frequency curves at S-49. **Figures C-16** through **C-18** present comparison of observed and simulated daily flow and stage at S-49. In general there are good agreement between observed and simulated values. The daily flow has less agreement as explained previously. **Table C-6** presents the runoff coefficients for C-24 basin. There are over 20 % time that the observed runoff rainfall ratio excessed 50 %, which are considered as questionable.

The results indicate that the parameter values used in the C-23 and C-24 basins can be applied to the rest of the St. Lucie Estuary Watershed where there are lack of observed data for model calibrations and applications.

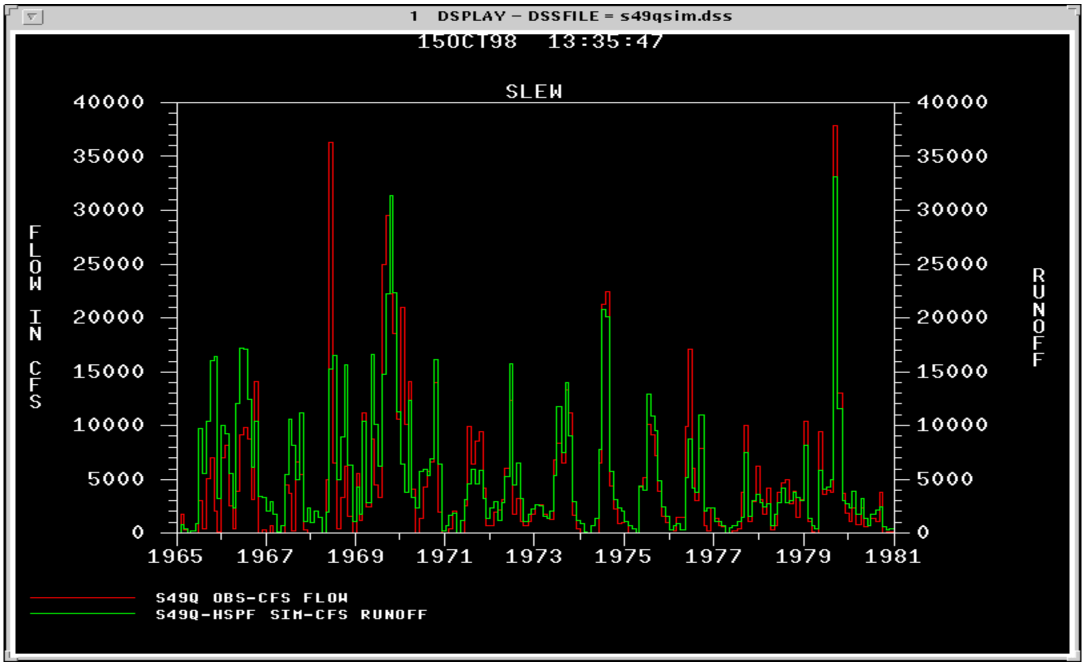

Figure C-12. Observed and Simulated Monthly Flow with Irrigation Scheme (1965-1980).

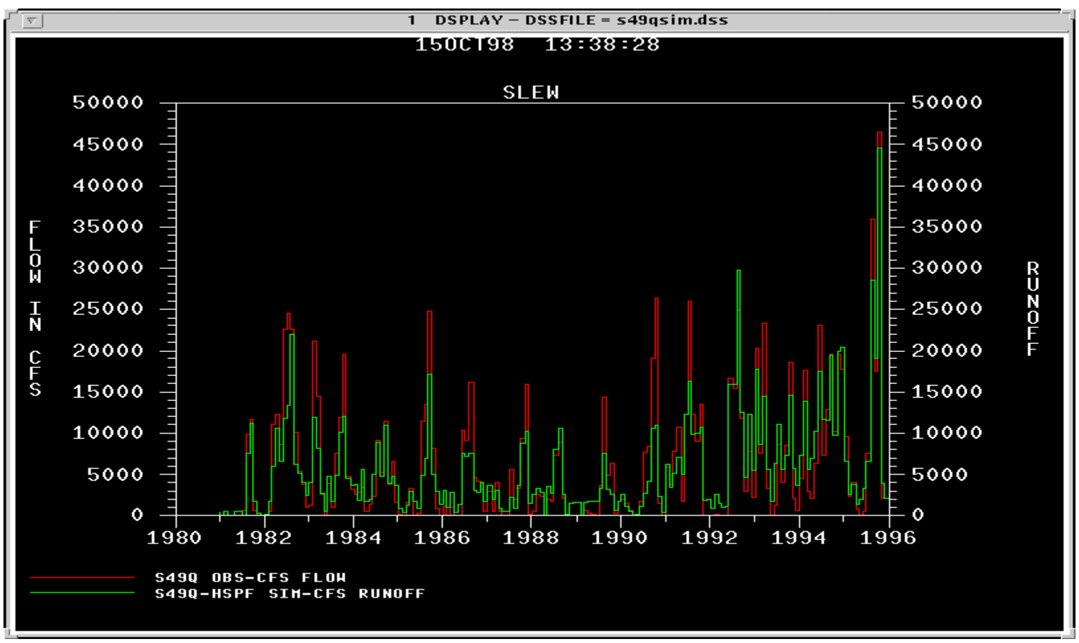

Figure C-13. Observed and Simulated Monthly Flow with Irrigation Scheme (1981-1995).

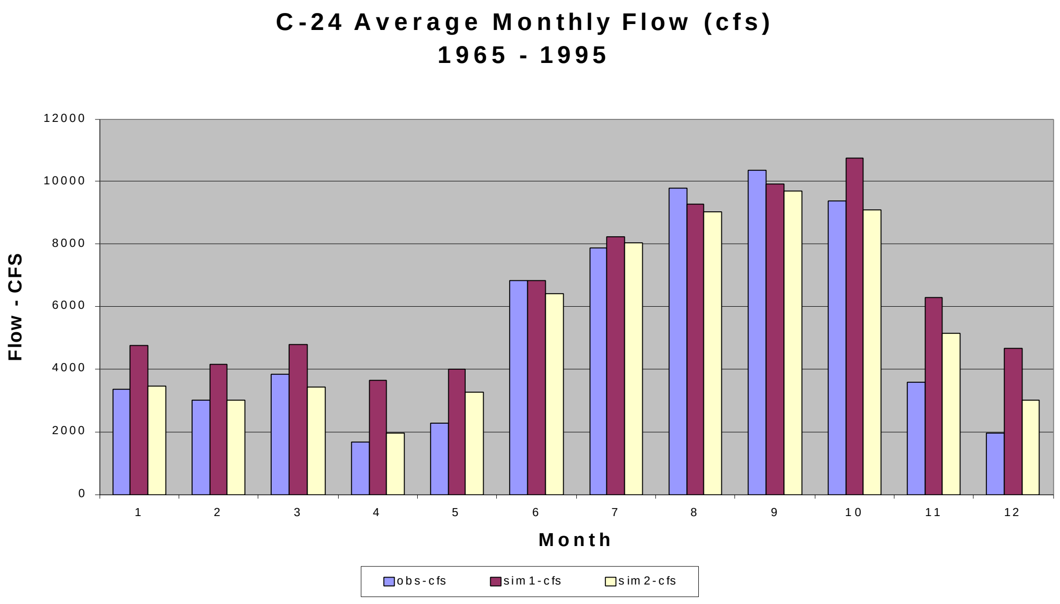

Figure C-14. Comparison of Observed and Simulated Averaged Monthly Flows from C-24 Basin.

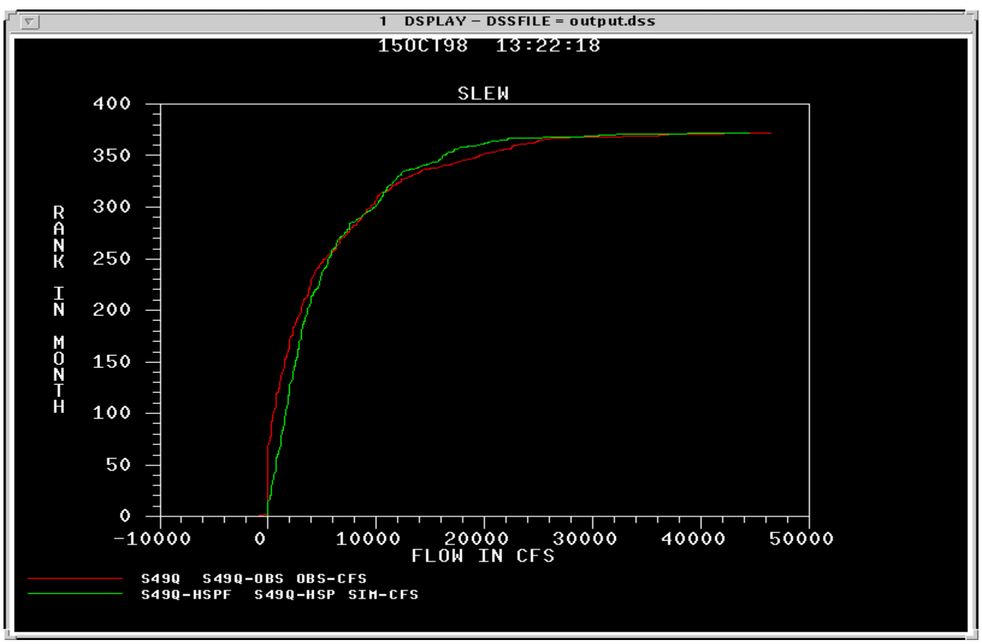

Figure C-15. Comparison of Observed and Simulated Monthly Frequency Curves at S-49.

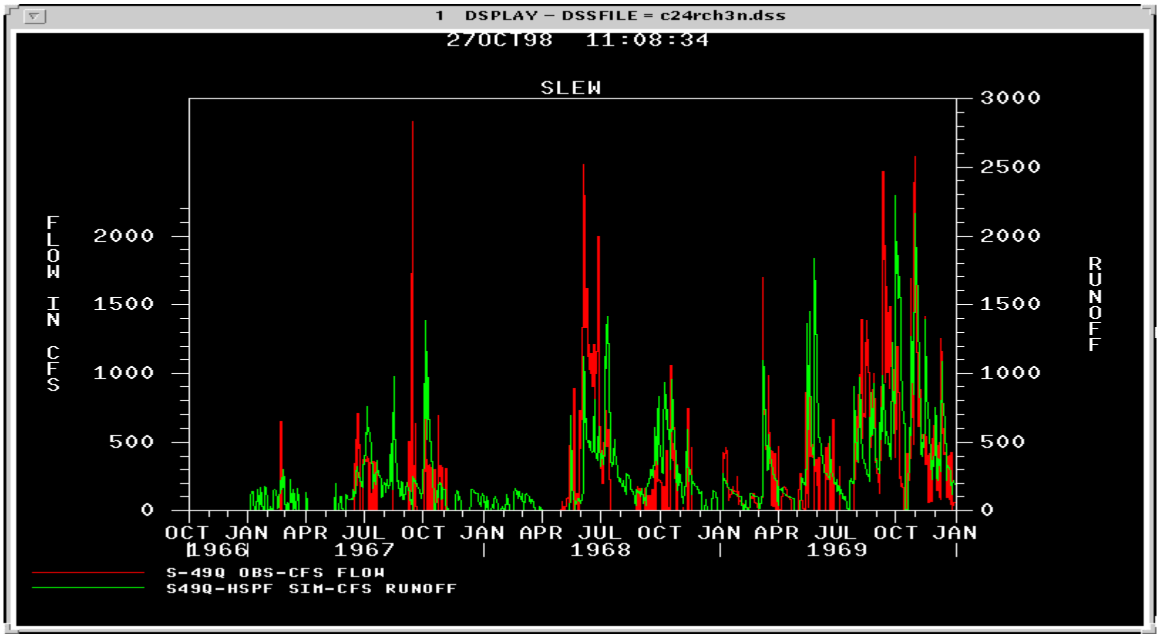

Figure C-16. Comparison of Observed and Simulated Daily Flow at S-49 (1966-69).

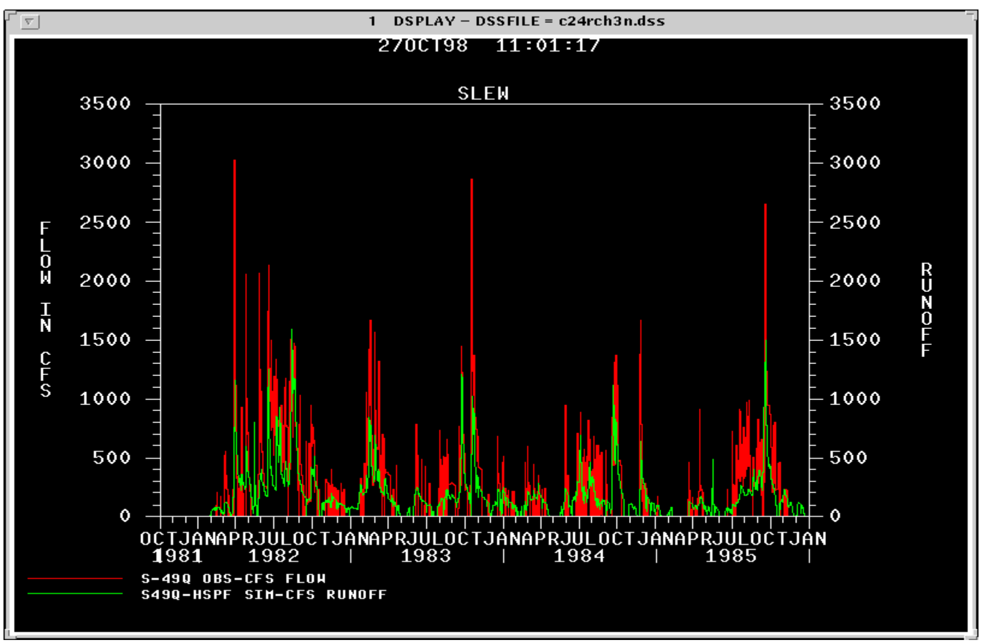

Figure C-17. Comparison of Observed and Simulated Daily Flow at S-49 (1981-85).

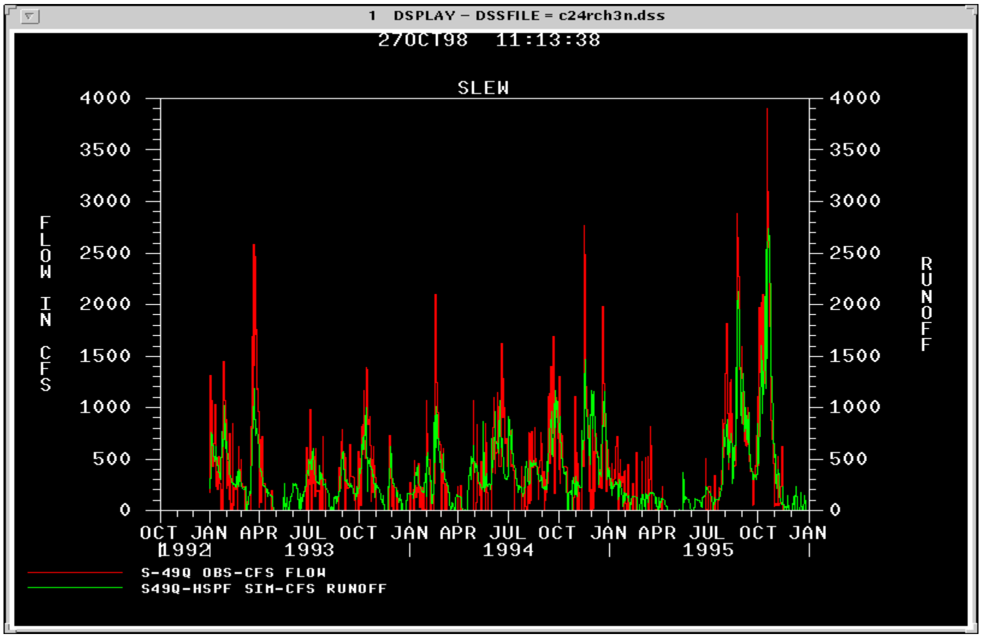

Figure C-18. Comparison of Observed and Simulated Daily Flow at S-49 (1992-95).

WATER BUDGET FOR ST. LUCIE ESTUARY WATERSHED

Table C-8 presents the completed water budget for the watershed based on the HSPF modeling analysis:

Table C-8. Water Budget for the Watershed

Parameter	inches/year	inches/year	ac-ft/year
Rainfall	52.17	52.17	2,169,613
Potential ET	64.00		
Actual ET	35.31	-35.31	-1,468,361
Irrigation:			
From stream (71%)	2.48		
From Floridan & LO (29%)*	1.44	1.44	59,945
Landuse runoff	20.67		
Basin runoff	18.32	-18.32	-761,883
Balance		-0.02	-686

*Note that irrigation from Floridan is considered as external source.

Actual Evapotranspiration from Each Land Use*

Land Use	inches/year	acres	ac-ft/year
Forest	36.43	40,358	122,521
Groves	39.50	140,331	461,926
Pastures	34.51	141,140	405,913
Urban Impervious	10.17	29,982	25,413
Urban pervious	34.88	44,951	130,663
Wetland	37.77	102,271	321,924
Basin	35.31	499,034	1,468,361

Note: * Approximate values.

Runoff from Each Land Use*

Land use	inches/year	acres	ac-ft/year
Forest	15.84	40,358	53,278
Groves	26.39	140,331	308,653
Pastures	16.91	141,140	198,851
Urban pervious	18.12	44,951	67,862
Urban impervious	43.06	29,982	107,598
Wetland	14.49	102,271	123,528
Basin	20.67	499,034	859,770

Note: * Approximate values.

Irrigation

Source	inches/year-groves	acres	ac-ft/year	in./yr-basin
From stream	8.81	140,331	102,989	2.48
From Floridan & LO	5.13	140,331	59,945	1.44
Total	13.93	140,331	162,934	3.92

The water budgets for each basin of the St. Lucie Estuary Watershed are provided in **Tables C-9** through **C-16**. HSPF model has a built in water budget balance check at each time step. The slightly unbalance shown in the table was caused primary due to truncation and runoff error used in the spreadsheet.

Table C-9. Water Budget for C-23 Basin

	Inches/year	**inches/year**	**ac-ft/year**
Rainfall	50.70	50.70	473,298
Potential ET	64.00		
Actual ET	36.64	-36.64	-342,002
Irrigation from stream	2.32		
Irrigation from Floridan	0.93	0.93	8,655
Landuse runoff	17.33		
Basin runoff (HSPF)	15.28	-15.28	-142,643
Basin runoff (observed)	13.88		
Balance		-0.29	-2,692

Actual ET from Each Land Use*

	Inches/year	acres	ac-ft/year
Forest	36.66	5,387	16,455
Groves	39.15	34,596	112,860
Pastures	34.85	47,128	136,876
Urban Impervious	13.42	1,273	1,423
Urban Pervious	34.85	1,887	5,480
Wetland	38.03	21,743	68,907
Basin	36.64	112,013	342,002

Runoff from Each Land Use*

	Inches/year	**acres**	**ac-ft/year**
Forest	13.79	5,387	6,190
Groves	21.74	34,596	62,668
Pastures	15.61	47,128	61,302
Urban Impervious	37.29	1,273	3,954
Urban Pervious	15.61	1,887	2,454
Wetland	12.72	21,743	23,039
Basin	17.33	112,013	159,607

Irrigation for Groves

	Inches/year	**acres**	**ac-ft/year**	**in/yr-basin**
Irrigation from stream	7.51	34,596	21,638	2.32
Irrigation from Floridan	3.00	34,596	8,655	0.93
Total	10.51	34,596	30,293	3.25

Note: * Approximate values.

Table C-10. HSPF Water Budget for C-24 Basin

	Inches/year	inches/year	ac-ft/year
Rainfall	50.95	50.95	386,305
Potential ET	64.00		
Actual ET	35.03	-35.03	-265,643
Irrigation :			
From stream	3.20		
From Floridan	1.28	1.28	9,697
Landuse runoff	20.23		
Basin runoff (HSPF)	17.16	-17.16	-130,092
Basin runoff (observed)	16.70		
Balance		0.04	267

Actual ET from Each Land Use*

	Inches/year	acres	ac-ft/year
Forest	35.26	6,968	20,472
Groves	37.85	20,646	65,115
Pastures	33.70	41,827	117,476
Urban Impervious	13.52	1,184	1,333
Urban Pervious	33.70	1,775	4,986
Wetland	36.32	18,589	56,260
Basin	35.03	90,988	265,643

Runoff from Each Land Use*

	Inches/year	acres	ac-ft/year
Forest	15.42	6,968	8,952
Groves		20,646	
Pastures	16.98	41,827	59,198
Urban Impervious	37.43	1,184	3,692
Urban Pervious	16.98	1,775	2,513
Wetland	14.65	18,589	22,691
Basin	20.23	90,988	153,401

Irrigation

	In/yr-groves	acres	ac-ft/year	in/yr-basin
From stream	14.09	20,646	24,242	3.20
From Floridan	5.64	20,646	9,697	1.28
Total	19.74	20,646	33,939	4.48

*Note: approximate values.

Table C-11. HFPS Water Budget for Basins 4, 5, and 6

	Inches/year	inches/year	ac-ft/year
Rainfall	53.91	53.91	66,268
Potential ET	64.00		
Actual ET	31.62	-31.62	-38,865
Irrigation	0.00		
Landuse runoff	22.11		
Basin runoff (HSPF)	22.12	-22.12	-27,181
Basin runoff (observed)	NA		
Balance		0.17	222

Note: NA mean not available.

Actual ET from Each Land Use*

	Inches/year	acres	ac-ft/year
Forest	36.29	3,491	10,559
Groves	34.74	420	1,217
Pastures	34.59	2,530	7,293
Urban Impervious	12.24	2,510	2,561
Urban Pervious	34.59	3,766	10,855
Wetland	37.67	2,033	6,381
Basin	31.67	14,750	38,865

Runoff from Each Land Use*

	Inches/year	acres	ac-fty/year
Forest	17.34	3,491	5,046
Groves	18.96	420	664
Pastures	19.06	2,530	4,018
Urban Impervious	41.68	2,510	8,719
Urban Pervious	19.06	3,766	5,981
Wetland	16.26	2,033	2,753
Basin	22.11	14,750	27,181

*Note: approximate values.

Irrigation

Irrigation for groves assumed insignificant.

Table C-12. HSPF Water Budget for S-153 Basin

	Inches/year	inches/year	ac-ft/year
Rainfall	47.41	47.41	51,045
Potential ET	64.00		
Actual ET	33.59	-33.59	-36,167
Irrigation	0.00		
Landuse runoff	13.70		
Basin runoff (HSPF)	13.70	-13.70	-14,746
Basin runoff (observed)	NA		
Balance		0.12	132

Actual ET from Each Land Use for S-153 Basin*

	Inches/year	acres	ac-ft/year
Forest	34.65	1,428	4,124
Groves	32.88	2,069	5,670
Pastures	32.68	4,129	11,244
Urban Impervious	8.47	447	316
Urban Pervious	32.68	671	1,828
Wetland	37.32	4,175	12,985
Basin	33.59	12,920	36,167

Runoff from Each Land Use for S-153 Basin*

	Inches/year	acres	ac-ft/year
Forest	12.49	1,428	1,486
Groves	14.42	2,069	2,486
Pastures	14.47	4,129	4,977
Urban Impervious	38.95	447	1,452
Urban Pervious	14.47	671	809
Wetland	10.16	4,175	3,534
Basin	13.70	12,920	14,746

*Note: approximate values.

Irrigation

Irrigation assumed as insignificant

Table C-13. HSPF Wter Budget for South Fork Basin

	Inches/year	inches/year	ac-ft/year
Rainfall	53.71	53.71	212,775
Potential ET	64.00		
Actual ET	33.31	-33.31	-131,941
Irrigation	0.00 (assume insignificant)		
Landuse runoff	20.23		
Basin runoff (HSPF)	20.23	-20.23	-80,145
Basin runoff (observed)	NA		
Balance		0.17	689

Actual ET from Each Land Use*

	Inches/year	acres	ac-ft/year
Forest	35.87	4,548	13,592
Groves	34.06	6,409	18,193
Pastures	34.16	14,706	41,860
Urban Impervious	12.39	3,928	4,055
Urban Pervious	34.16	5,892	16,772
Wetland	37.30	12.053	37,468
Basin	33.31	47,537	131,941

Runoff from Each Land Use*

	Inches/year	acres	ac-ft/year
Forest	17.56	4,548	6,654
Groves	19.44	6,409	10,385
Pastures	19.28	14,706	23,626
Urban Impervious	41.33	3,928	13,530
Urban Pervious	19.28	5,892	9,467
Wetland	16.41	12,053	16,484
Basin	20.23	47,537	80,145

Table C-14. HSPF Water Budget for C-44 Basin

	Inches/year	inches/year	ac-ft/year
Rainfall	53.26	53.26	515,258
Potential ET	64.00		
Actual ET	38.32	-38.32	-370,774
Irrigation from stream	2.96		
Irrigation from Lake Okeechobee (VanZee)	3.12	3.12	30,191
Landuse runoff	21.03		
Basin runoff (HSPF)	17.91	-17.91	-173,293
Basin (observed)	NA		
Balance		0.14	1,383

Actual ET from Each Land Use*

	Inches/year	acres	ac-ft/year
Forest	37.28	7,490	23,265
Groves	40.77	48,873	166,049
Pastures	35.57	25,372	75,212
Urban Impervious	13.91	1,724	1,999
Urban Pervious	35.57	2,587	7,668
Wetland	38.57	30,049	96,581
Basin	38.32	116,095	370,774

Runoff from Each Land Use*

	Inches/year	acres	ac-ft/year
Forest	16.02	7,490	10,000
Gorves & Cane	26.63	48,873	108,469
Pastures	17.74	25,372	37,508
Urban Impervious	39.67	1,724	5,700
Urban Pervious	17.74	2,587	3,824
Wetland	15.00	30,049	37,568
Basin	21.03	116,095	203,069

Irrigation

	In/yr-grove	acres	ac-ft/year	in/yr-basin
From stream	7.02	48,873	28,604	2.96
From Lake Okeechobee (VanZee)	7.41	48.873	30,191	3.12
Total	14.45	48,873	58,795	6.08

Table C-16. HSPF Water Budget for North Fork Basin

	Inches/year	inches/year	ac-ft/year
Rainfall	53.24	53.24	464,665
Potential ET	64.00		
Actual ET	32.42	-32.42	-282,970
Irrigation from stream	3.27		
Irrigation from Floridan	1.31	1.31	11,402
Landuse runoff	25.47		
Basin runoff (HSPF)	22.20	-22.20	-193,777
Basin runoff (observed)	NA		
Balance		-0.08	-680

Actual ET from Each Land Use*

	Inches/year	acres	ac-ft/year
Forest	36.99	11,047	34,054
Groves	40.78	27,317	92,821
Pastures	35.13	5,448	15,953
Urban Impervious	8.71	18,916	13,074
Urban Pervious	35.13	28,373	83,074
Wetland	38.16	13,630	43,341
Basin	32.42	104,731	282,970

Runoff from Each Land Use*

	Inches/year	acres	ac-ft/year
Forest	16.24	11,047	14,949
Groves	29.71	27,317	67,625
Pastures	18.11	5,448	8,222
Urban Impervious	44.76	18,916	70,552
Urban Pervious	18.11	28,373	42,815
Wetland	15.37	13,630	17,458
Basin	25.47	104,731	221,621

Irrigation

	In/yr-grove	acres	ac-ft/year	in/yr-basin
From stream	12.52	27,317	28,505	3.27
From Floridan	5.01	27,317	11,402	1.31
Total	17.53	27,317	39,907	4.57